Analysis of a Late Quaternary Deposit and Small Mammal Fauna from Nettle Cave, Jenolan, New South Wales.

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A deposit of small mammal bones in Nettle Cave, part of the Jenolan Caves system, was excavated. The bone deposit appears to be the result of owl pellet accumulation. A pair of Sooty Owls (*Tyto tenebricosa*) currently inhabits a roosting site within the cave. The deposit was excavated to a depth of 68 cm, which represents an accumulation throughout the last glacial recession in the late Pleistocene to the present. Two radiocarbon dates (7,140 ± 280 and 8,730 ± 280 BP) were obtained from discrete charcoal lenses in the middle layers of the deposit. Analyses of small mammal remains and sediments indicate climatic conditions during the late Pleistocene were colder and drier than at present, becoming warmer and wetter in the Holocene. The apparent abrupt extinction of *Burramys parvus* and the rapid decline in abundance of *Mastacomys fuscus* in the Jenolan area are attributed to a brief humid period that occurred in southeastern Australia at around 15,000 to 14,000 BP.

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KEY WORDS: Nettle Cave, owl pellet accumulation, *Tyto tenebricosa*, late Quaternary, *Burramys parvus*, sediments, climate.

INTRODUCTION

Fossil deposits have long been used as a basis for the interpretation of past environments. In Australia, various Quaternary cave deposits have been analysed and used to reconstruct the faunal and climatic history of the surrounding area (e.g., Balme et al. 1978, Baynes 1987, Baynes et al. 1976, Hope et al. 1977, Porter 1979, Wakefield 1972). Deposits containing small mammal remains have been found to be particularly useful (Lundelius 1963).

Little fossil material had been found in Jenolan Caves until a collection of bones was analysed from a small cave overlooking the lower carpark (Hope 1979). Infrequent discoveries of isolated skeletal remains from various caves have been reported in subsequent years. This study involved excavation of a fossil deposit in Nettle Cave, part of the Jenolan Caves system. The excavation yielded an abundance of intact small mammal bones, including those belonging to now locally extinct taxa, together with avian postcranial material and a few agamid and scincid mandibles (which are not discussed in this paper).

MATERIALS, METHODS AND STUDY AREA

The Jenolan Caves Reserve is situated on the Great Dividing Range (33°47'S,

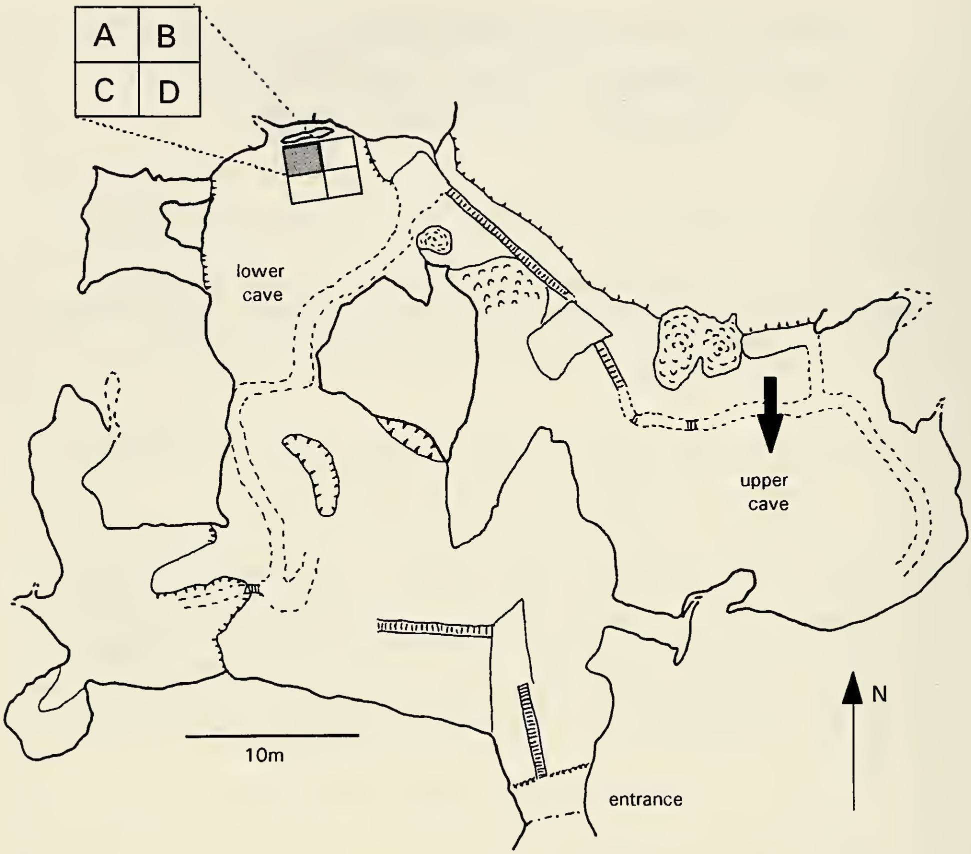


Figure 1. Plan of Nettle Cave, Jenolan, with the area of heaviest deposition of owl pellets outlined (lower cave). The highlighted area is the quadrat selected randomly for excavation. This area was further subdivided into quarters as shown in the insert. The quadrat and the subdivided areas are not to scale. The current Sooty Owl roost is indicated by the arrow (upper cave). (modified from Cox et al. 1989).

150°02'E; 1,100–1,200 m a.s.l.) approximately 110 km west of Sydney. This area has a maximum yearly mean temperature of 16.6°C and a minimum of 8.0°C (recorded at Katoomba - approximately 30 km from Jenolan). The average annual precipitation is 1,412 mm with the greatest rainfall occurring between December and June. The vegetation within the Jenolan Caves Reserve supports eight major vegetation communities (Lembit 1988) ranging from open forest to cleared land.

Nettle Cave is a high-level entrance into the Devil's Coach House, which is itself a natural tunnel approximately 80 m high and 40 m wide (Cox et al. 1989). Flowstone forms a false floor in Nettle Cave (Anon. 1988). Cave conditions are dry (Nettle Cave is about 20 m above modern flood levels), with an annual temperature range from below zero to 30°C (Cox et al. 1989). The cave receives light from the entrance in the south, from a roof-hole in the northeast and from Arch Cave in the southwest (Fig. 1).

The fossil deposit examined in this study is concentrated beneath a rock ledge in the roof of Nettle Cave close to the northern wall of the lower cave (Fig. 1). A pair of Sooty Owls (*Tyto tenebricosa*) currently occupies a nocturnal roosting site in the north-facing wall of the upper Nettle Cave (Fig. 1). Sooty Owls were first reported roosting in

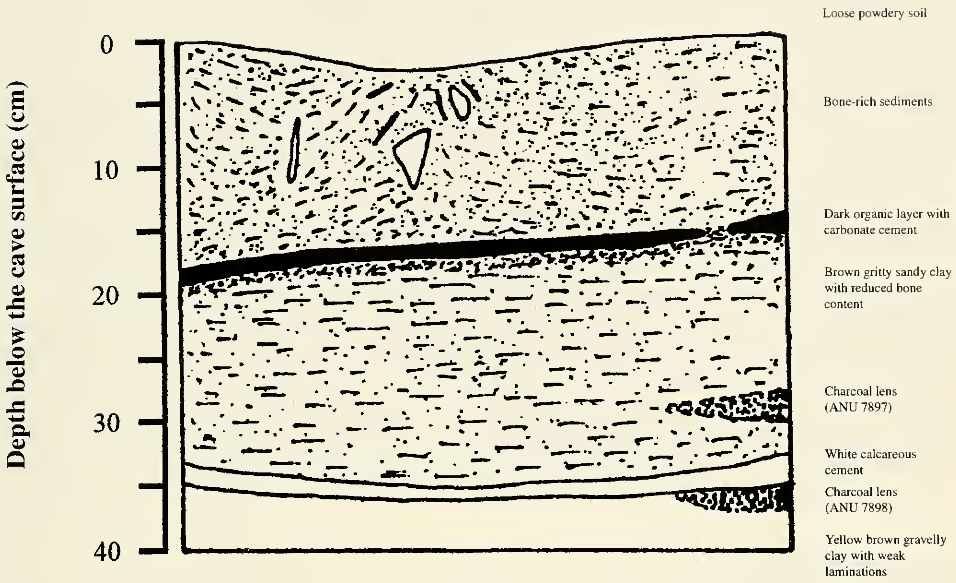


Figure 2. Stratigraphy of the upper levels of the southern wall of the excavated pit in the owl pellet deposit, Nettle Cave.

Nettle Cave late last century by Jeremiah Wilson (the first official guide at Jenolan) (E. Holland, pers. comm.). The nocturnal roosting site is thought to communicate with the rock ledge in the lower cave by a tunnel in the roof of the cave (E. Holland, pers. comm.). The pair of Sooty Owls appears to roost diurnally in the roof of the Devil's Coach House.

In July 1990, owl pellets and bone material associated with disintegrated pellets were collected from the surface of an area of approximately 2 x 2 m directly beneath the rock ledge in the roof of the lower Nettle Cave. On 10 January 1991, three fresh pellets were collected approximately 4.5 m from the northwestern wall of the lower cave.

Excavation

Excavation of the deposit began in January 1991. An area measuring 1.5 x 1.5 m was pegged over the site of heaviest deposition with one side abutting the northeastern wall (Fig. 1). A test dig was begun adjacent to the pegged area; its dimensions were about 50 x 50 cm and 58 cm deep. The dig proved to be rich in bone to this depth. Charcoal lenses were found at 28 cm and 35 cm.

A quadrant measuring roughly 75 x 75 cm was chosen at random for excavation (Fig. 1). A section drawing of the southern wall of the excavation is shown in Fig. 2. Spits (defined in this paper as arbitrary vertical divisions, with respect to the stratigraphy in the deposit) from 0–5 cm, 5–13 cm, 13–25 cm and 25–35 cm were excavated. The deposit to 35 cm below the present cave floor was rich in bone.

Below 35 cm the main excavation was subdivided into four areas of roughly equal size (A, B, C and D) (Fig. 1) and excavated separately. Two centimetre layers (here defined as natural vertical intervals of sediments, in which conditions of formation in each layer appear to have been consistent) were removed, following the line of the sediment, from 35 to 41 cm. These layers contained less bone than above. The bones were found in association with small aggregates of sediment cemented by calcium carbonate. A limestone outcrop was apparent at 37 to 41 cm on the eastern wall of the pit, but receded beyond the wall of the pit below 41 cm.

The sediment was heavily cemented by calcium carbonate below 41 cm. Excavation of quadrants A and C (Fig. 1) became impossible. Excavation of quadrants B and D from 41 to 44 cm was possible by using the sharp end of a trowel to break up the sediment.

At 44 cm the sediment from quadrant D and the outer part of quadrant B was so firmly cemented that further excavation of this section of the pit with the hand-held implements available was impossible. The remainder of quadrant B contained bone in a relatively soft sediment. This area was excavated to a depth of 68 cm. Spits ranging from 2 to 5 cm in depth were removed from 44 to 68 cm of the excavation. Excavation ceased in April 1991 at a depth of 68 cm, despite bone being visible below this point. The excavation was not backfilled as is customary because the Jenolan Caves Scientific Advisory Committee plans to line the walls of the excavation with perspex covers and use the pit as an exhibit.

Sediment Samples

Sediment samples were taken every 5 cm, or every 2 cm if the stratigraphic layer was narrower, from the inner part of the southern wall of quadrant B (Fig. 1). A total of 16 samples was taken to a depth of 64 cm. The pH of each sample was determined in the field by using a CSIRO test kit. The method of measuring particle size and the particle size classification follow Folk (1968).

Carbon Samples

Although minor amounts of charcoal were present throughout the levels (here defined as any point on the vertical axis of the deposit) of the excavation, usable quantities were only located in two lenses at 28–29 cm and 35–36 cm depth in the western wall of the main pit. The lenses were sampled for radiocarbon dating using the methods of Gupta and Polach (1985) and submitted to the Australian National University Radiocarbon Laboratory. For sample ANU-7897 (Nettle Cave 28–29 cm), possible contaminants were removed and the sample washed in hot 10% HCl, rinsed and dried to remove possible carbonate. For sample ANU-7898 (Nettle Cave 35–36 cm), the sample was wet sieved and the fraction <500 um taken for dating. After solvent extraction, the sample was washed in boiling HCl, and NaOH insoluble residue (non-humic) was re-acidified, rinsed and dried.

Preparation of the Bone Remains

All surface material and subsamples from 0–5 cm were washed in water and air-dried. Material from 13 cm downwards required acid treatment (10% acetic acid for seven days) for separation of bone from matrix. Levels 5–13 cm and 39–41 cm were not analysed because of time constraints.

Identification of Mammalian Material

Each depth interval (here defined as a vertical division between two measured levels within the excavation, e.g. 0–5 cm) was analysed separately. The upper levels of the deposit contained relatively more intact maxillary and dentary specimens than the lower levels. All maxillary and dentary material bearing teeth or with tooth sockets, and isolated teeth were identified.

Marsupials and rodents were identified by comparing maxillary and dentary fragments and isolated teeth with published descriptions (Appendix A) and with reference specimens held at the University of NSW and the Australian Museum. Microchiropteran specimens were identified by S.J. Hand.

Dental nomenclature of marsupials follows Luckett (1993). Marsupial specimens were considered to be juvenile if the P3 and/or M4 had not fully erupted. Edentulous mandibular specimens were regarded as juvenile according to size variation recorded in the literature and by comparison with reference material.

Nomenclature generally follows that of Walton (1988) and Walton and Richardson (1989). *Pseudocheirus peregrinus* and *Petauroides volans* are referred to Pseudocheiridae (Archer 1984), and *Acrobates pygmaeus* to Acrobatidae (Aplin and Archer 1987).

The identified mammalian and unidentified avian material will be lodged at the Australian Museum (the reptile specimens were sent to the South Australian Museum for identification and cataloguing, and are lodged there).

Quantitative Methods

In order to make inferences regarding the composition of the mammalian assemblage, the minimum number of individuals (MNI) of each taxon represented in each analysed depth interval was determined. Estimation of the MNI follows Baynes et al. (1976). Identifiable right and left dentaries and maxillae were counted separately. The most numerous element was taken as the MNI. Relative abundance was taken as the percentage of all species occurring in each depth interval. (These percentages give a more accurate representation of each species from depth interval to depth interval than does the MNI.)

RESULTS

Sedimentary Analyses

Stratigraphy

A section drawing of the southern wall of the excavated pit is shown in Fig. 2. Because cementation by calcium carbonate made definition of the stratification of the lower layers difficult, only the top 40 cm of the excavation are shown. The gross stratigraphy of the bone-rich sediment suggests these sediments had formed as a result of a series of deposits of air-fall debris. The dark organic layer indicates a stable surface. The sediment changed below this layer to a brown, gritty, sandy clay that contained an increased amount of charcoal and soil particles, but a reduced amount of bone. Two discrete lenses of charcoal were evident. Between these lenses was a white, calcareous, cemented layer which may represent a former water saturation level. The sediment below this cemented layer to the base of the pit contained a yellow-brown, gravelly clay which may have been the result of water ponding in the cave. There was no clear stratification below 40 cm.

Sediment Chemistry

The field pH measurements were uniformly 9.5 for the 16 sediment samples. An alkaline environment promotes the precipitation of calcium carbonate out of solution and the rapid decomposition of organic material by bacteria and fungi (Levinson 1982).

Radiocarbon Dates

Radiocarbon ages are reported in Table 1 as conventional years BP. $d^{13}C$ values were estimated and given an error of 2.0 permil. The two radiocarbon ages are significantly different ($p>0.05$).

TABLE 1 Radiocarbon ages of charcoal from the Nettle Cave deposit.

Sample code	Depth (cm)	d14C (permil)	δ13C (permil)	D14C (permil)	age (years BP)
ANU-7897	28–29	- 587.8 ± 13.7	- 24.0 ± 2.0	- 588.6 ± 13.8	7,140 ± 280
ANU-7898	35–36	- 661.9 ± 11.4	- 24.0 ± 2.0	- 662.6 ± 11.5	8,730 ± 280

Source of the Sediment

Mineral magnetic results from the Nettle Cave sediment samples are compared with data from other sites in the Jenolan Caves catchment (Stanton 1989) in Table 2. The results indicate that the Nettle Cave sediments are distinct from these possible sources and especially from the Mammoth Cave fluvial sediments.

TABLE 2 Mean magnetic parameters for different sediment source areas, Jenolan catchment. SIRM denotes saturation isothermal remanent magnetisation. Data other than that for Nettle Cave from Stanton (1989).

Source area	Mean susceptibility	Mean frequency dependent susceptibility	Mean SIRM
Nettle Cave	1.43	9.9	20.6
Terrace Creek	4.24	6.9	41.4
Jenolan-Bindo Creek Divide	4.41	7.9	49.6
Western Ridge	9.24	4.2	109
Mammoth Cave Fines	4.24	5.4	39.9
Mammoth Cave Coarse	3.7	5.2	32.5

Particle size analysis can provide some information on sediment transport and deposition (Krumbein and Sloss 1963). The relative amounts (by weight) of gravel, sand, silt and clay in each sample from the Nettle Cave deposit are illustrated in Fig. 3. (Unfortunately, bone was included in the gravel fraction; if bone had been excluded, the relative proportions of sand, silt and clay would be greater than that suggested in Fig. 3.) The greatest fluctuations, albeit minor, were in the proportions of gravel and then sand. An increase in the amount of fine material occurred around 37 cm. This increase was coincident with water ponding of the top layer in the lower zone of the deposit. The preponderance of coarser, angular particles in the sediment samples suggests that the sediment is of local origin and has not been subjected to lengthy fluvial transport.

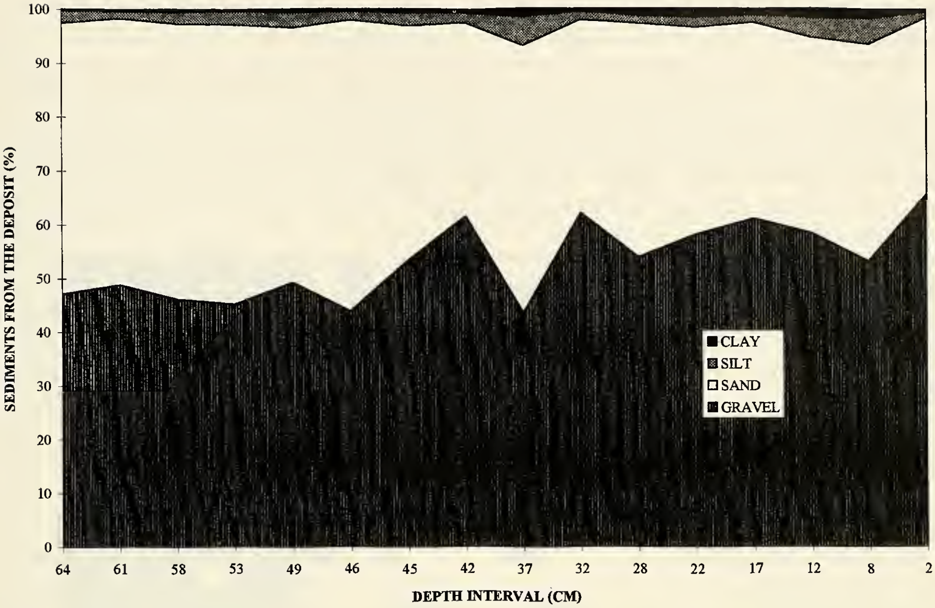


Figure 3. Graphical representation of the amount of gravel, sand, silt and clay (by weight) in the sediments from the Nettle Cave deposit.

Considering the mineral magnetic data and particle size of the Nettle Cave sediments, these sediments are likely to have originated from local soil above the cave. Moreover, the relatively minor fluctuations in the proportions of the sediments throughout the depth of the deposit suggest there was little variation in the source of the sediments.

Mammal Fauna from the Nettle Cave Deposit

Thirty-five species of mammals were identified in the Nettle Cave deposit (Appendix B). Of these species, 74% are extant and 26% are extinct either locally or in southeastern Australia.

If a species is present in an upper or lower level of the deposit, it tends to appear throughout the upper or lower zone of the deposit, respectively (Table 3). The distribution of some species at 41 to 44 cm appears to be discontinuous.

The majority of the species occurring throughout the deposit (Table 3) are small animals weighing less than 200 g. All these specimens are adult. The larger species present, e.g. *Dasyurus* sp., *P. peregrinus*, *Isoodon obesulus* and *Perameles nasuta*, are represented by subadults.

Species with restricted habitat requirements and range of distribution are the most useful indicators of environmental conditions (Baynes et al. 1976). The changes in relative abundance with time of selected non-volant, small mammal species from the Nettle Cave deposit are illustrated in Fig. 4. These species were selected as indicators of possible environmental change in the Jenolan area for the following reasons:

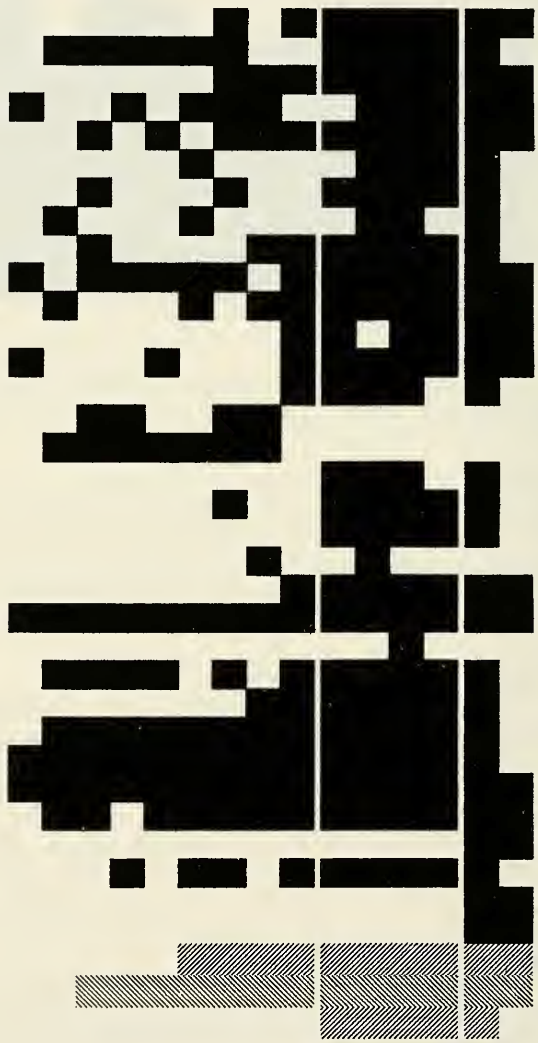
1. the species showed a change in distribution over time or,

2. the species showed a change in abundance over time and

TABLE 3 Summary of Appendix B: Presence or absence of specimens identified from each depth interval from the Nettle Cave deposit. Presence of species in a depth interval is indicated by a black block. Depth intervals 13–5 cm and 41–39 cm were not analysed, and are represented as narrow, blank bars. S = number of non-volant mammal species in the deposit. n=sum of the MNIs of non-volant mammal species, excepting *A.* spp., *S.* sp., *P.* spp. and *R.* spp. 1. Presence of bats in a depth interval is indicated by a dashed block, but the MNI is not included in n. 2. Presence of birds is indicated by a dashed block; specimens were not identified above order. 3. Skinks were present in depth intervals 5–0 cm and 25–13 cm; agamids were present in depth intervals 5–0, 25–13, 35–25, 37–35 and 39–37 cm.

SPECIES

Antechinus stuartii sensu lato
A. swainsonii
A. flavipes
A. spp.
Sminthopsis murina
S. sp.
Phascogale tapoatafa
Dasyurus sp. cf. *D. viverrinus*
Isoodon obesulus
Perameles nasuta
Pseudocheirus peregrinus
Petauroides volans
Petaurus breviceps
Cercartetus nanus
C. lepidus
Burramys parvus
Acrobates pygmaeus
Potorous sp. cf. *P. tridactylus*
Bettongia sp.
Thylogale thetis
Conilurus albipes
Pseudomys oralis
P. gracilicaudatus
P. australis
P. novaehollandiae
P. fumeus
P. spp.
Mastacomys fuscus
Rattus fuscipes
R. rattus
R. spp.
Mus musculus
Oryctolagus cuniculus
Bats[1]
Birds[2]
Lizards[3]



Depth interval	S	n
Surface	14	119
5–0 cm	25	1400
25–13 cm	19	717
35–25 cm	23	911
37–35 cm	22	452
39–37 cm	21	371
43–41 cm	16	101
44–43 cm	12	35
46–44 cm	14	76
50–46 cm	9	41
54–50 cm	10	37
59–54 cm	8	33
64–59 cm	12	28
66–64 cm	9	14
68–66 cm	4	11

3. the species' habitat requirements are both well-documented and restricted.

Modern Mammal Fauna in the Jenolan Area

The term 'modern mammal fauna' is used to describe the fauna inhabiting, or thought to inhabit, the Jenolan area since European settlement. Of the 35 mammal species recovered from the Nettle Cave deposit (Table 3), one (*Conilurus albipes*) is presumed to be extinct (Watts and Aslin 1981); eight (*Dasyurus viverrinus*, *Cercartetus lepidus*, *Burramys parvus*, *Bettongia* sp., *Pseudomys fumeus*, *Pseudomys australis*, *Pseudomys oralis* and *Mastacomys fuscus* are extinct in the area (Strahan 1995; Watts and Aslin 1981); *Pseudomys gracilicaudatus* had previously occurred this far south (remains were found in superficial deposits at Walli Caves near Canowindra and Wombeyan Caves [Mahoney and Posamentier 1975]); the status of *Phascogale tapoatafa* and *Pseudomys novaehollandiae* in this area is uncertain (Strahan 1995; Watts and Aslin 1981); the remaining 23 are locally extant (Strahan 1995).

DISCUSSION

Age of the Deposit

The age of specimens in the Nettle Cave deposit can be estimated when associated with stratigraphy, other fauna, radiometric dates and the appearance of the material (after the manner of Baynes (1987)).

Two radiocarbon dates based on charcoal samples were obtained from the middle levels of the deposit (Fig. 2). If one assumes a constant rate of accumulation of sediments to the base of the excavation at 68 cm, then this level may represent 16,000–14,000 years BP. However, ponding and a change in the nature of sedimentation is evident below 35–36 cm (Fig. 2). In addition, abrupt changes in the faunal assemblage around 41–43 cm may indicate either a hiatus in deposition, or a minor unconformity (period of nondeposition or erosion) in the deposit (Krumbein and Sloss 1963). Conversely, changes in the composition of the material being deposited may have produced the change in stratification (Dunbar and Rodgers 1963). For example, changes in grain size may cause pronounced layering. Therefore, this time frame on the basis of sedimentation should be treated with caution, since charcoal was not available at the base of the pit to allow more precise dating.

Environmental History at Jenolan based on Nettle Cave Sediments

Although real precipitation at the end of the Pleistocene was reputedly low (Dodson 1977; Galloway 1965), seasonal melting of the snow would have made available free water. A study by one of us (D.G., unpublished data) suggests the influx of subsoil particles to the lower levels of the Nettle Cave deposit indicates erosion of the topsoil overlying the cave either due to hillslope instability (Gillieson et al. 1985) or thawing of the ground and subsequent washing away of this surface material. Wind activity would have contributed to the erosion to some degree. More importantly, wind activity is a selective barrier in the transport of particular grains. Coarse particles such as gravel are left behind or deposited close to the source forming a local accumulation. Fine grains (silt and clay) are kept in suspension and transported over long distances (Krumbein and Sloss 1963; Pettijohn 1957; Reineck and Singh 1975). These conditions are reflected in the relatively low amounts of silt and clay in the Nettle Cave sediments (Fig. 3).

The sediment in the levels of the deposit around 44–41 cm consists of a yellow-brown, gravelly clay which was probably the result of local water ponding in the cave.

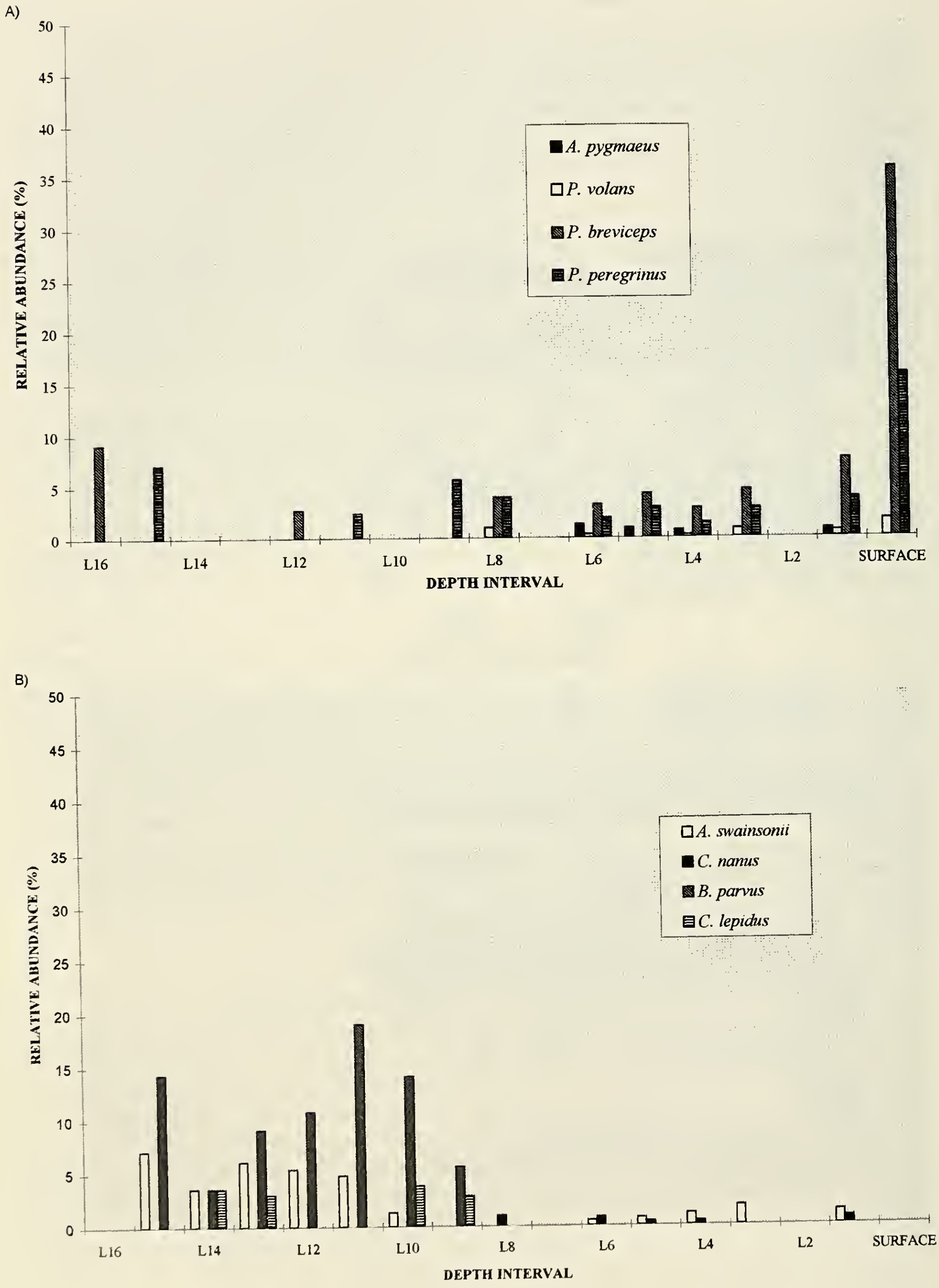


Figure 4. The relative abundance of selected non-volant, native mammal species from the Nettle Cave deposit. The species represented are possible indicators of climatic change. Levels L2 and L7 were not analysed. See Appendix B for the corresponding depth interval to each level. Continued on following page.

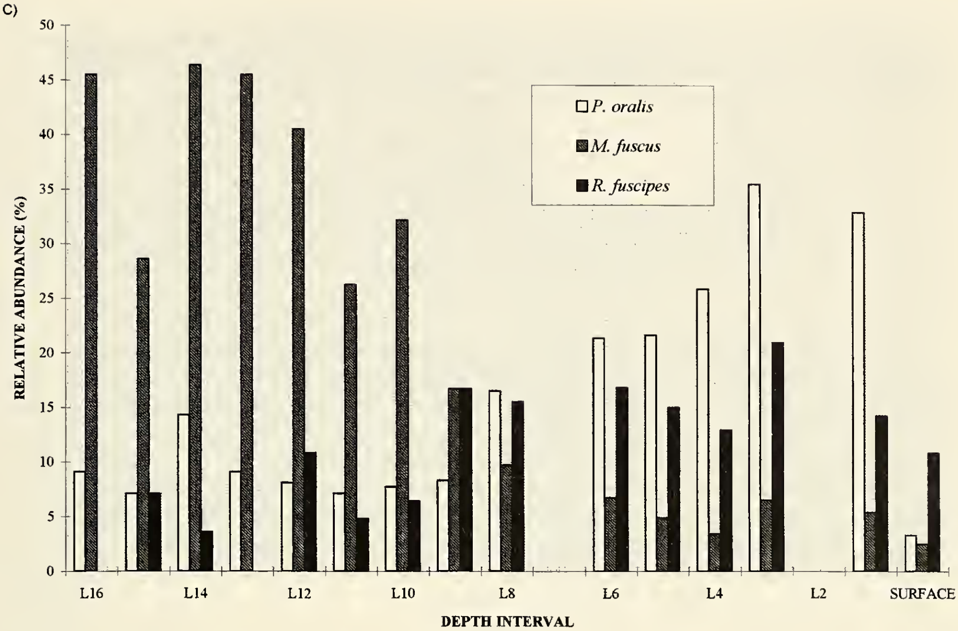


Figure 4. Continued from previous page.

Ponding may have occurred from surface water seeping into the limestone and accumulating behind the cave wall. Numerous runnels on the wall behind the excavation suggest water inflowing. Leaching to the lower layers would have followed. An increase in the amount of fine material (Fig. 3) at these levels corresponds with more humid conditions, a phenomenon reported by Wells et al. (1984) for Victoria Cave. Consolidation of parts of these levels may have been due to the introduction of cementing material in the early stages of diagenesis, rather than from compaction (Krumbein and Sloss 1963). In fact, alkaline conditions and an increase in temperature would enhance the precipitation of calcium carbonate which in turn would promote cementation of the sediment (Pettijohn 1957; Reineck and Singh 1975).

The radiocarbon dates of 7,140 ± 280 and 8,730 ± 280 BP agree well with the sedimentary analyses. Between the two charcoal lenses was a white, calcareous, cemented layer (Fig. 2). Its formation appears to have coincided with the wettest period at 7,500 to 5,000 BP (Bowler et al. 1976). Relative increases in the proportion of fine particles at 37 cm (Fig. 3) indicate wetter conditions. These conditions seem to correlate with the early to mid-Holocene humid period (Bowler et al. 1976; Colhoun et al. 1982). Drier conditions throughout the remainder of the Holocene (Bowler et al. 1976; Hooley et al. 1980) are reflected in the proportionately low amounts of clay and silt in the upper levels of the Nettle Cave sediments (Fig. 3). However, particle size analysis of these sediments indicates the drier conditions of the late Holocene were still wetter than the conditions experienced in the late Pleistocene.

Mode of Deposition

Sooty Owls are the current source of small mammal bone deposits in Nettle Cave. We consider that owls of some species have been the source of the deposit over the entire period of deposition covered by our excavation for the following reasons:

1. Long bones are intact; skulls are either intact (except for a damaged or absent occiput) or broken into their component bones; mandibles are rarely heavily fragmented; and little erosion of bone and tooth has taken place.

2. There is a bias towards smaller animals, particularly murids and small dasyurids; the larger species are represented by subadults or juveniles.

3. Evidence for collection by diurnal raptors, e.g. kestrels, such as heavy digestive erosion of bones and tooth enamel (Andrews 1990; Kusmer 1990) is absent. Evidence for mammalian carnivores, e.g. *Sarcophilus* or *Thylacinus*, such as highly fragmented bones (especially skulls), eroded teeth and bone-bearing coprolites (Lundelius 1966) is also absent.

4. There is no evidence for fluvial deposition from the sedimentological data.

While the material from the Nettle Cave deposit fulfils the requirements of an owl accumulation (Lundelius 1966), it is impossible to conclude that Sooty Owls have been responsible for the entire deposit. Occupation of the roosting site may have alternated between Masked Owls (*Tyto novaehollandiae*) and Sooty Owls for the duration of pellet deposition. Both species have been found living in caves (Anon. 1988; J. Calaby, pers. comm., in Wakefield 1960; pers. obs.) and take similar prey items of comparable sizes (Table 4). Powerful Owls (*Ninox strenua*) may also have contributed to the deposit. However, the Powerful Owl habitually roosts in trees rather than caves (Fleay 1944) and is a more specialist predator, taking mid- to large-size arboreal species almost exclusively (Fleay 1944; James 1980; Kavanagh 1988; Tilley 1982) (Table 4). The almost total absence of moderate-size arboreal mammals in the lower levels of the deposit (Table 3), prey known to be taken by Sooty Owls and Masked Owls, suggests a lack of trees in the Jenolan area at this time. A lack of trees would also make it unlikely that Powerful Owls would have been present, given their habitat preference for forests (Kavanagh 1988) and therefore, they were unlikely to have contributed to the Nettle Cave deposit.

Environmental History at Jenolan based on Mammal Remains

The Nettle Cave faunal assemblage containing *B. parvus* (Table 3) appears to be late Pleistocene in age. The presence of *B. parvus* together with *M. fuscus* and *Antechinus swainsonii* throughout this early phase of the deposit indicates a colder environment than at present in the Jenolan area (Table 5). Modern *B. parvus* is physiologically intolerant of high temperatures (Fleming 1985) and is restricted to high alpine areas in NSW and Victoria. The presence of these species and the virtual absence of arboreal mammals suggest the vegetational formation was dominated by open areas with a dense ground cover of grasses and low shrubs. Conversely, the low representation of arboreal mammals may be due to a smaller owl as predator, rather than a lack of trees. However, the absence of *A. pygmaeus* and the low abundance of *Petaurus breviceps* in the lower zone of the deposit probably reflects the available vegetation at the time rather than predator bias, given that owls will take arboreal mammals if they are present (Table 4). The presence of *M. fuscus* may indicate the immediate presence of water (Hope et al. 1977), either as snow, running streams or wet microhabitats in the grasslands. Small pockets of forest or woodland were likely to have been present at lower altitudes.

The faunal composition of the lower levels of the Nettle Cave deposit appears to broadly correspond to the assemblage described in the Pleistocene fraction of the Pyramids deposit at Buchan (Wakefield 1969, 1972) and the entire Wombeyan breccia (Ride 1960). The relatively higher abundance of *M. fuscus* and *B. parvus* and lower abundance of *A. swainsonii* and arboreal species in the lower Nettle Cave deposit compared with the relative abundances of these species in the older fraction of the Pyramids deposit, suggest a less heavily forested vegetation in the Jenolan area, although sampling

TABLE 4 A list of the recorded prey items of the Sooty Owl, Masked Owl and Powerful Owl from the literature. a = adult, j = juvenile, yes denotes that the species is taken as prey by that particular owl, ? = this prey is possibly taken. 1. Howe (1935); Hyem (1979); Loyn et al. (1986); Schodde and Mason (1980); Smith (1984). 2. Hyem (1979); Mooney (pers. comm.). 3. Hyem (1979); James (1980); Kavanagh (1988); Seebeck (1976); Tilley (1982).

Prey species	Sooty Owl[1] (*Tyto tenebricosa*)	Masked Owl[2] (*T. novaehollandiae*)	Powerful Owl[3] (*Ninox strenua*)
Petaurus breviceps	yes	yes (a, j)	yes (a)
P. australis			yes
Pseudocheirus peregrinus	yes (a, j)	yes (a)	yes (a, j)
Petauroides volans	yes (j)		yes
Trichosurus vulpecula		yes (j)	yes (j)
Cercartetus nanus	yes	yes (a)	
C. lepidus		yes (a)	
Acrobates pygmaeus	yes		
Antechinus stuartii	yes		yes
A. swainsonii	yes		yes
A. minimus		yes (a)	
Sminthopsis leucopus		yes	
Phascogale tapoatafa			yes
Dasyurus maculatus		yes (a)	
D. viverrinus		yes (a, j)	
Isoodon obesulus		yes (j)	
Perameles gunnii		yes (a, j)	
Bettongia gaimardi		yes (a)	
Potorous tridactylus		yes (a)	
Thylogale thetis			?
T. billardierii		yes (j)	
Hydromys chrysogaster		yes (a)	
Mastacomys fuscus	yes	yes (a)	
Pseudomys fumeus	yes		
P. higginsi		yes (a, j)	
Rattus fuscipes	yes		yes (a)
R. lutreolus		yes (a)	
R. rattus	yes	yes (a)	
R. norvegicus		yes (a)	
Mus musculus		yes (a)	
Felis cattus		yes (j)	
Lepus capensis		yes (j)	
Oryctolagus cuniculus		yes (j)	yes
Bats		yes	yes
Insects	?	yes	yes
Birds	yes	yes	yes
Frogs		yes	

TABLE 5 Habitat data on the native, non-volant mammal species which occur in the Nettle Cave deposit. M.A.R. = mean average rainfall, ? denotes no rainfall data for that species. yes denotes the species is present in that habitat, yes ++ denotes the species is abundant in that habitat. For generic names, see Table 3. 1. Aitken (1977); 2. Braithwaite (1979); 3. Broome (1995); 4. Broome and Mansergh (1989); 5. Calaby (1988); 6. Calaby and Wimbush (1964); 7. Cockburn (1995); 8. Covacevich and Easton (1974); 9. Cuttle (1988); 10. Dickman (1982, 1995); 11. Fox (1995); 12. Godsell (1995); 13. Green (1995); 14. Happold (1989, 1995); 15. Heinsohn (1966); 16. Johnston (1995); 17. King and Mackowski (1986); 18. Lunney (1995); 19. Mahoney and Posamentier (1975); 20. Marlow (1958); 21. McKay (1988); 22. Ride (1970); 23. Soderquist (1995); 24. Stodart (1995); 25. Turner (1988); 26. Wakefield (1969, 1972); 27. Wakefield and Warneke (1967); 28. Watts and Aslin (1981).

Species	Associated with water	Ground cover/ Understorey	Dry sclero-phyll forest	Wet sclero-phyll forest	Wood-land	Rain-forest	Alpine heathland	Alpine shrubs	Heath-land	Scrub	Dry shrubland	Grass-land	Cultiv-ated land	M.A.R. (mm)	References
A. stuartii		thick ground cover	yes	yes ++										500–1,900	2, 26, 27
A. swainsonii	yes	dense understorey		yes			yes							>1,000	10, 26
A. flavipes			yes	yes	yes	yes ++								?	20, 27
S. murina			yes		yes				yes					?	11, 20
P. tapoatafa		thin ground cover	yes		yes									500–1,300	9, 20, 23, 26
D. viverrinus		rocky	yes		yes				yes	yes			yes	500–900	12, 20, 26
I. obesulus		good cover	yes		yes				yes					800–1,000	15, 22, 26
P. nasuta		little ground cover	yes	yes		yes								800–1,900	20, 24, 26
P. peregrinus		dense shrubs	yes	yes	yes	yes								500–1,900	20, 21, 22, 26
P. volans			yes	yes	yes									1,000–1,800	20, 21, 22, 26
P. breviceps			yes	yes ++	yes									500–1,900	20, 22, 26
C. nanus			yes	yes		yes								500–1,300	20, 22, 25, 26
C. lepidus			yes	yes						yes	yes			300–1,200	1, 13, 26
B. parvus		rocky with sparse ground cover		yes				yes	yes					1,300–2,400	3, 4, 5, 26
A. pygmaeus			yes	yes	yes									250–1,900	20, 22, 26
P. tridactylus		thick ground cover	yes	yes	yes	yes			yes	yes				760–1,300	16, 20, 22, 26
T. thetis				yes		yes								?	20, 22
C. albipes					yes									500–900	26, 28
P. oralis	yes	dense ground cover	yes	yes										?	8, 17, 28
P. gracilicaudatus		dense understorey	yes	yes					yes ++					?	8, 19, 28
P. australis												yes		?	8, 28
P. novaehollandiae		well-developed understorey	yes						yes					650–1,150	26, 28
P. fumeus		diverse understorey	yes	yes	yes				yes					900–1,900	7, 26, 28
M. fuscus	yes	dense ground cover		yes	yes		yes							1,500–2,500	6, 14, 26, 28
R. fuscipes	yes	dense ground cover		yes	yes	yes				yes				?	18, 28

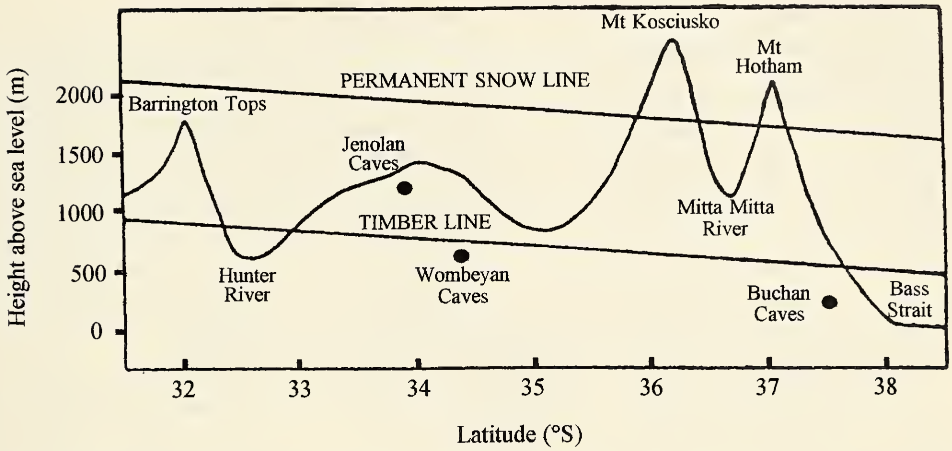


Figure 5. An altitude profile from Barrington Tops to Bass Strait with the location of *Burramys parvus* fossils from the Pleistocene, and the estimated position of the tree-line and permanent snowline during the height of glaciation at that time. However, the position of the snowline should be higher. The positions of the Buchan and Wombeyan Caves have been lowered from that indicated by Caughley (1986) to that stated by Wakefield (1969). The scale on the ordinate axis has been lowered so Bass Strait is at sea level. (modified after Caughley 1986).

bias from different predators at the two sites cannot be ruled out. The higher altitude of Nettle Cave lends support to the former scenario. Caughley (1986) estimated the position of the tree-line at the height of glaciation during the late Pleistocene to be below the Jenolan, Wombeyan and Buchan Caves (Fig. 5). However, altitudinal data from Wakefield (1969) indicate the tree-line would have been above the Buchan and Wombeyan Caves at this time. While periglacial activity did not reach the southern flanks of the Blue Mountains (Peterson 1968), the ground may have been seasonally frozen (Gillieson et al. 1985). The apparent presence of trees at Jenolan indicates the tree-line had shifted up and climatic warming in the highlands of southeastern Australia had begun. Wakefield (1969, 1972) identified the older fraction of the Pyramids deposit as having accumulated over the period covering most of the glacial recession phase at the termination of the Pleistocene. This agrees well with the climatic and vegetational sequences indicated by the faunal composition and sedimentological data of the lower Nettle Cave deposit.

The age of the Nettle Cave deposit cannot be estimated with any certainty on the rate of sedimentation alone. However, from the faunal evidence and comparison with the Pyramids deposit and the climatological data from southeastern Australia (Bowler et al. 1976; Galloway and Kemp 1981), the lower levels of the Nettle Cave deposit appear to have accumulated after the glacial maximum, about 20,000 years ago (Frakes et al. 1987), to around 15,000 BP.

Following this early phase was a transition period, represented by approximately 44–41 cm of the deposit, and correlating with the period 15,000 to 10,000 BP. This period was marked by an abrupt change in the composition and/or abundance of the faunal assemblage in the deposit (Table 3, Appendix B) along with a change in the sediments (Fig. 3). *Burramys parvus* and *C. lepidus* were no longer represented, the abundance of *A. swainsonii* and *M. fuscus* was greatly reduced while the numbers of *Rattus fuscipes*, *P. peregrinus*, *P. volans* and *P. breviceps* suddenly increased. While absence from the deposit and discontinuity of distribution of some species at around 44–41 cm (Table 3) may indicate a change of predator, the presence of other species throughout the deposit, such as *Dasyurus* sp., *I. obesulus*, *P. nasuta* and most native murids, suggests changes in abundance of most species were the result of changing climatic conditions.

As previously mentioned, *B. parvus* is physiologically intolerant of high temperatures (Fleming 1985). The presumed abrupt local extinction of *B. parvus* may therefore indicate a sudden increase in temperature. The zoogeographic range of *B. parvus* may have started to narrow during the brief period of humidity at 15,000 to 14,000 BP (Bowler et al. 1976). The presence of *A. swainsonii* and *M. fuscus* indicates cold conditions (Table 5). The lower abundance of these species in the 44–41 cm of the deposit suggests warmer conditions than previously experienced. An increase in abundance of *R. fuscipes* occurred at around the same time (Appendix B). Changes in vegetation at the close of the Pleistocene from grasslands, with grasses being a major food source for *M. fuscus*, to a ground cover dominated by ferns and shrubs, the preferred habitat of *R. fuscipes*, may have given *R. fuscipes* a competitive advantage, thereby maintaining a lower population of *M. fuscus* in the Jenolan area throughout the Holocene.

The local extinction of *C. lepidus* cannot be explained by climatic change alone. The modern distribution of this species includes hot and dry conditions (Aitken 1977; Dixon 1978). The coexistence of *B. parvus* and *C. lepidus* throughout the late Pleistocene suggests the latter species is capable of tolerating climatic extremes. The disappearance of *C. lepidus* from the Jenolan area may be attributed to a possible lack of floristic diversity at the time. It has been claimed that modern *C. lepidus* is highly mobile, and follows plants as they flower throughout the year (Ward 1992). As the Jenolan area became more heavily forested towards the end of the Pleistocene, *C. lepidus* may have been replaced by its larger congener, *C. nanus*.

The presence of arboreal species in the upper levels of the deposit suggests the presence of open forest and woodland. These vegetational communities were well established by 11,500 to 9,000 BP (Kershaw 1981). A combination of increased real precipitation (Bowler et al. 1976; Kershaw 1981) and an increase in temperature (Binder and Kershaw 1978) around this period may have contributed to the forestation. Increased wetness is evident from the nature of the sediments in the deposit (Fig. 3), while the continued low representation of *A. swainsonii* and *M. fuscus* is suggestive of warmer conditions.

The upper levels of the Nettle Cave deposit (c. 41– 0 cm) appear to have accumulated throughout the Holocene. The mammal species in the deposit indicate both wet and dry sclerophyll forest and woodland with varying amounts of ground cover (Table 5). The vegetation in the Jenolan area throughout the Holocene therefore appears to have been much the same as that found in the area today.

The upper levels of the Nettle Cave deposit broadly resemble the younger fraction of the Pyramids deposit. The species composition from this fraction of the Nettle Cave deposit gives no indication of an arid period, as proposed by Wakefield (1969, 1972) for the Pyramids deposit, but rather a change to perhaps slightly drier conditions. The faunal assemblage from the final phase of the transition period in the Nettle Cave deposit is comparable with the assemblage from the most recent Pleistocene sediments of the Pyramids deposit.

The cave surface mammal fauna (Table 3) closely resembles the modern mammal fauna in the Jenolan area with a few notable exceptions. Introduced species are found with species no longer extant in the area (*P. oralis* and *M. fuscus*) or extinct (*C. albipes*). Mixing of the deposit, possibly by rock-wallabies, or humans when the cave was open to tourists, may have occurred at the surface and top level of excavation (0–5 cm). Mixing is quite likely because the appearance of the bone from the surface differs from white to pale grey for the introduced species, to a yellow-cream for the native species. The colour of the bones from 0–5 cm varies from pale to dark grey for the introduced species, compared with yellow-cream to dark orange for the native murids. Wakefield (1972) concluded that variation in colour is correlated with age, whereby the lighter coloured bones represent a more recent age than the darker coloured bones. Differential colouration of

TABLE 6 Proposed correlation of events from the Nettle Cave data.

Years BP	Levels of the deposit	Mammals in the deposit	Events at Nettle Cave	Vegetation	Climate	Contemporaneous events
c.20,000–15,000	68–44 cm	Small mammal fauna: *B. parvus*, *C. lepidus*, *M. fuscus* & *A. swainsonii*	Erosion of topsoil above cave. Low amounts of silt & clay in the deposit	Dominated by grasses; small pockets of forest & wood-land at lower altitudes	Conditions were very cold & dry; maximum aridity 17,500–16,000 BP	Deglaciation began before 15,000 BP Accumulation of the Pleistocene fraction of the Pyramids Cave deposit & the entire Wombeyan breccia
15,000–10,000	44–41 cm	*B. parvus* & *C. lepidus* locally extinct; *M. fuscus* & *A. swainsonii* nos reduced; *R. fuscipes* & arboreal spp. nos increased	Water ponding in the cave; increased amounts of silt & clay; possible hiatus in deposition	Open forest & woodland established by 11,500–9,000 BP	Period of humidity from 15,000–14,000 BP; wetter, warmer conditions; becoming slightly drier towards the end of this period	Accumulation of the most recent Pleistocene level of the Pyramids deposit corresponds with the final phase of this period
10,000– present	41–0 cm	Small mammal fauna similar to that found in the area today; abundance of arboreal spp. increased, while abundance of native murids decreased in modern times	Radiocarbon dates of 7,140 & 8,730 BP from these levels; increase in amount of silt & clay corresponding to period of humidity; low amounts in other levels	Wet & dry sclerophyll forest & wood-land, much the same as at present	Period of humidity from 7,500–5,000 BP; wetter, warmer conditions; drier conditions followed, but still wetter than late Pleistocene	Accumulation of the Holocene fraction of the Pyramids deposit

bone occurred according to the depths at which the bones were initially deposited. The presence of different coloured bones together suggests mechanical mixing of layers after colour alteration of the bones had taken place, that is, the darker, older bones from a lower level were mixed with the lighter coloured, younger bones from a more superficial level. Therefore, by using Wakefield's (1972) colour-age criterion, it may be assumed that there was limited temporal overlap between these introduced and native species. However, this assumption should be treated cautiously given that stratigraphic control of the excavation was not sufficient to detect this overlap. Therefore, *C. albipes*, *P. oralis* and *M. fuscus* may have been contemporaries of the introduced species. It is possible that the local extinction of these three native mammals was a result of the introduction of non-native mammals associated with European settlement (Wakefield 1960; Watts and Aslin 1981), e.g., rodents and rabbits. Distributional data on *P. australis* (Watts and Aslin 1981), *P. novaehollandiae* (Keith and Calaby 1968; Strahan 1995) and *P. fumeus* (Watts and Aslin 1981) in conjunction with the colour of the bones of these species from 0–5 cm, suggest they were not contemporaneous with the introduced species.

On the basis of the Nettle Cave data, major extinctions of the small mammal fauna in the Jenolan area at the end of the Pleistocene do not appear to have occurred. Two species (*B. parvus* and *C. lepidus*) probably became locally extinct at this time. The most parsimonious explanation for most of the faunal changes at the end of the Pleistocene is that of climatic change, particularly an increase in temperature. Local extinction of *M. fuscus*, *P. oralis* and *C. albipes* at the time of European settlement was possibly the result of competition from introduced species.

A Summary of the Chronology of Events

The available geomorphological and palaeontological evidence from the Nettle Cave deposit and the proposed correlation with other events is summarised in Table 6.

The small mammal assemblage represented in the lower Nettle Cave deposit (68–c. 44 cm) appears to be late Pleistocene in age. We suggest this fraction of the deposit was accumulated during the glacial recession at the terminal phase of the Pleistocene, i.e. after 20,000 to 15,000 BP. Conditions were colder and with less real precipitation than at present. The vegetation was dominated by shrubs and a dense ground cover, with pockets of wet sclerophyll forest. The disappearance of *B. parvus* from the Nettle Cave deposit is attributed to the increase in temperature in southeastern Australia over the period 15,000 to 14,000 BP. A brief hiatus in deposition may have followed. The appearance of arboreal species may signify the revegetation of the area by forest and/or woodland. This event corresponds with the period of increased precipitation from 11,500 to 9,000 BP. This transition period of increased wetness is represented by ponding at roughly 44–41 cm of the deposit.

The small mammal assemblage represented in the upper levels (41–0 cm) of the Nettle Cave deposit is identified as Holocene. A wet forest fauna is suggested to have inhabited the area during the early to mid-Holocene. Drier conditions, much the same as the modern vegetational communities in the Jenolan area today, followed this early Holocene humid phase. However, this period was wetter than that in the late Pleistocene.

The surface of the deposit is modern. Mixing with the upper levels of the Holocene fraction occurred. Modern specimens could be distinguished from specimens deposited prior to European settlement largely on the basis of discolouration of the bone. Local extinctions, most notably of rodents, possibly occurred after European settlement as a consequence of competition from introduced mammals.

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REFERENCES

Aitken, P.F. (1977). The Little Pygmy Possum (*Cercartetus lepidus* [Thomas]) found living on the Australian mainland. *South Australian Naturalist* **51**, 63–66.

Andrews, P. (1990). 'Owls, caves and fossils'. (University of Chicago Press: Chicago).

Anon. (1988). 'Jenolan Caves Reserve; Draft Plan of Management, volume 2 Specialist Papers'. (Draft Plan prepared by Cameron McNamara, Sydney; published by Tourism Commission of New South Wales and Crown Lands Office: Sydney).

Aplin, K.P. and Archer, M. (1987). Recent advances in marsupial systematics with a new syncretic classification. In 'Possums and opossums: studies in evolution' (Ed. M. Archer) pp. 15–72. (Surrey Beatty and Sons and the Royal Zoological Society: Sydney).

Archer, M. (1981). Results of the Archbold Expeditions, number 104. Systematic revision of the marsupial dasyurid genus *Sminthopsis* Thomas. *Bulletin of the American Museum of Natural History* **168**, 61–224.

Archer, M. (1984). The Australian marsupial radiation. In 'Vertebrate zoogeography and evolution in Australasia' (Eds M. Archer and G. Clayton) pp. 633–808. (Hesperian Press: Carlisle, Western Australia).

Balme, J., Merrilees, D. and Porter, J.K. (1978). Late Quaternary mammal remains, spanning about 30,000 years, from excavations in Devil's Lair, Western Australia. *Journal of the Royal Society of Western Australia* **61**, 33–65.

Baynes, A., (1987). The original mammal fauna of the Nullarbor and southern peripheral regions: evidence from skeletal remains in superficial cave deposits. In 'A biological study of the Nullarbor Region South and Western Australia in 1984' (Eds N.L. McKenzie and A.C. Robinson) pp. 139–152. (South Australian Department of Environment and Planning: Adelaide).

Baynes, A., Merrilees, D. and Porter, J.K. (1976). Mammal remains from the upper levels of a late Pleistocene deposit in Devil's Lair, Western Australia. *Journal of the Royal Society of Western Australia* **58**, 97–126.

Binder, R. and Kershaw, A.P. (1978). A late Quaternary pollen diagram from the southeastern highlands of Australia. *Search* **9**, 44–45.

Bowler, J.M., Hope, G.S., Jennings, J.N., Singh, G. and Walker, D. (1976). Late Quaternary climates of Australia and New Guinea. *Quaternary Research* **6**, 359–394.

Braithwaite, R.W. (1979). Social dominance and habitat utilization in *Antechinus stuartii* (Marsupialia). *Australian Journal of Zoology* **27**, 517–528.

Broome, L.S. (1995). Mountain Pygmy-possum, *Burramys parvus*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 208–210. (Reed Books: Chatswood, NSW).

Broome, L.S. and Mansergh, I.M. (1989). The Mountain Pygmy Possum *Burramys parvus* (Broom) an alpine endemic. In 'The scientific significance of the Australian Alps' (Ed. R. Good) pp. 241–264. (Australian Alps National Parks Liaison Committee: Canberra).

Calaby, J.H. (1988). Mountain Pygmy-possum, *Burramys parvus*. In 'Australian Museum complete book of Australian mammals' (Ed. R. Strahan) pp. 168–169. (Angus and Robertson: Sydney).

Calaby, J.H. and Wimbush, D.J. (1964). Observations on the Broad-toothed Rat, *Mastacomys fuscus* Thomas. *CSIRO Wildlife Research* **9**, 123–133.

Caughley, J. (1986). Distribution and abundance of the Mountain Pigmy-possum, *Burramys parvus* Broom, in Kosciusko National Park. *Australian Wildlife Research* **13**, 507–516.

Cockburn, A. (1995). Smoky Mouse, *Pseudomys fumeus*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 598–599. (Reed Books: Chatswood, NSW).

Colhoun, E.A., van de Geer, G. and Mook, W.G. (1982). Stratigraphy, pollen analysis, and paleoclimatic interpretation of Pulbeena Swamp, northwestern Tasmania. *Quaternary Research* **18**, 108–126.

Covacevich, J. and Easton, A. (1974). 'Rats and mice in Queensland'. (Queensland Museum: Brisbane).

Cox, G., James, J.M., Osborne, R.A.L. and Leggett, K.E.A. (1989). Stromatolitic crayfish-like stalagmites. *Proceedings of the University of Bristol Spelaeological Society* **18**, 339–358.

Cuttle, P. (1988). Brush-tailed Phascogale, *Phascogale tapoatafa*. In 'Australian Museum complete book of Australian mammals' (Ed. R. Strahan) pp. 34–35. (Angus and Robertson: Sydney).

Davison, A. (1986). Dentition of Victorian *Antechinus* species (Marsupialia: Dasyuridae). *Australian Mammalogy* **9**, 73–85.

Dickman, C.R. (1982). Some ecological aspects of seasonal breeding in *Antechinus* (Dasyuridae, Marsupialia). In 'Carnivorous marsupials' (Ed. M. Archer) pp. 139–150. (Royal Zoological Society of NSW:

Sydney).

Dickman, C.R. (1995). Dusky Antechinus, *Antechinus swainsonii*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 98–99. (Reed Books: Chatswood, NSW).

Dixon, J.M. (1971). *Burramys parvus* Broom (Marsupialia) from Falls Creek area of the Bogong High Plains, Victoria. *Victorian Naturalist* **88**, 133–138.

Dixon, J.M. (1978). The first Victorian and other Victorian records of the Little Pigmy Possum *Cercartetus lepidus* (Thomas). *Victorian Naturalist* **95**, 4–7.

Dodson, J. (1977). Late Quaternary palaeoecology of Wyrie Swamp, southeastern South Australia. *Quaternary Research* **8**, 97–114.

Dunbar, C.O. and Rodgers, J. (1963). 'Principles of stratigraphy'. (John Wiley and Sons, Inc.: New York).

Fleay, D. (1944). Watching the Powerful Owl. *Emu* **44**, 97–112.

Fleming, M.R. (1985). The thermal physiology of the Mountain Pygmy-possum *Burramys parvus* (Marsupialia: Burramyidae). *Australian Mammalogy* **8**, 79–90.

Folk, R.L. (1968). 'Petrology of sedimentary rocks'. (Hemphill's: Austin, Texas).

Fox, B.J. (1995). Common Dunnart, *Sminthopsis murina*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 150–151. (Reed Books: Chatswood, NSW).

Frakes, L.A., McGowran, B. and Bowler, J.M. (1987). Evolution of Australian environments. In 'Fauna of Australia' (Eds G.R. Dyne and D.W. Walton) pp. 1–16. (Australian Government Publishing Service: Canberra).

Freedman, L. (1967). Skull and tooth variation in the genus *Perameles*. Part 1: Anatomical features. *Records of the Australian Museum* **27**, 147–166.

Freedman, L. and Joffe, A.D. (1967). Skull and tooth variation in the genus *Perameles*. Part 2: Metrical features of *P. nasuta*. *Records of the Australian Museum* **27**, 183–195.

Freedman, L. and Rightmire, G.P. (1971). Skull and tooth variation in Australian bandicoots (Peramelidae, Marsupialia): the genus *Isoodon* and multivariate comparisons with *Perameles*. *Journal of the Royal Society of Western Australia* **54**, 21–31.

Galloway, R.W. (1965). Late Quaternary climates in Australia. *Journal of Geology* **73**, 603–618.

Galloway, R.W. and Kemp, E.M. (1981). Late Cainozoic environments in Australia. In 'Ecological biogeography of Australia' (Ed. A. Keast) pp. 51–80. (Dr W. Junk bv Publishers: The Hague).

Gillieson, D., Spate, A. and Head, J. (1985). Evidence for cold-climate processes at Wombeyan Caves, Southern Tablelands, New South Wales. *Search* **16**, 46–47.

Godsell, J. (1995). Eastern Quoll, *Dasyurus viverrinus*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 70–71. (Reed Books: Chatswood, NSW).

Green, R.H. (1983). 'An illustrated key to the skulls of the mammals in Tasmania'. (Queen Victoria Museum and Art Gallery: Launceston).

Green, R.H. (1995). Little Pygmy-possum, *Cercartetus lepidus*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 215–216. (Reed Books: Chatswood, NSW).

Gupta, S.K. and Polach, H.A. (1985). 'Radiocarbon dating practices at A.N.U'. (Australian National University, Radiocarbon Dating Research Laboratory: Canberra).

Happold, D.C.D. (1989). Small mammals of the Australian Alps. In 'The scientific significance of the Australian Alps' (Ed. R. Good) pp. 221–239. (Australian Alps National Parks Liaison Committee: Canberra).

Happold, D.C.D. (1995). Broad-toothed Rat, *Mastacomys fuscus*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 562–564. (Reed Books: Chatswood, NSW).

Heinsohn, G.E. (1966). Ecology and reproduction of the Tasmanian bandicoots (*Perameles gunni* and *Isoodon obesulus*). *University of California Publications in Zoology* **80**, 1–96.

Hooley, A.D., Southern, W. and Kershaw, A.P. (1980). Holocene vegetation and environments of Sperm Whale Head, Victoria, Australia. *Journal of Biogeography* **7**, 349–362.

Hope, J.H. (1979). 'Quaternary fossil mammal localities in southeastern New South Wales and eastern Victoria'. (Unpublished manuscript: Research School of Pacific Studies, Australian National University, Canberra).

Hope, J.H., Lampert, R.J., Edmondson, E., Smith, M.J. and van Tets, G.F. (1977). Late Pleistocene faunal remains from Seton rock shelter, Kangaroo Island, South Australia. *Journal of Biogeography* **4**, 363–385.

Howe, F.E. (1935). Some field notes on the Sooty Owl. *Emu* **34**, 317–318.

Hyem, E.L. (1979). Observations on owls in the upper Manning River district, New South Wales. *Corella* **3**, 17–25.

James, J.W. (1980). Food of the Powerful Owl, *Ninox strenua*, in southeastern Queensland. *Emu* **80**, 34–35.

Johnston, P.G. (1995). Long-nosed Potoroo, *Potorous tridactylus*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 301–302. (Reed Books: Chatswood, NSW).

Jones, B. and Baynes, A. (1989). Illustrated key to Australian Mammalia to generic level. In 'Fauna of Australia. Mammalia, volume 1B' (Eds D.W. Walton and B.J. Richardson) pp. 1075–1157. (Australian Government Publishing Service: Canberra).

Kavanagh, R.P. (1988). The impact of predation by the Powerful Owl, *Ninox strenua*, on a population of the Greater Glider, *Petauroides volans*. *Australian Journal of Ecology* **13**, 445–450.

Keith, K. and Calaby, J.H. (1968). The New Holland Mouse, *Pseudomys novaehollandiae* (Waterhouse), in the Port Stephens district, New South Wales. *CSIRO Wildlife Research* **13**, 45–58.

Kershaw, A.P. (1981). Quaternary vegetation and environments. In 'Ecological biogeography of Australia' (Ed. A. Keast) pp. 81–101. (Dr W. Junk bv Publishers: The Hague).

King, G.C. and Mackowski, C.M. (1986). Two new localities for *Pseudomys oralis* Thomas (Rodentia: Muridae) in New South Wales. *Australian Mammalogy* **9**, 63–65.

Krumbein, W.C. and Sloss, L.L. (1963). 'Stratigraphy and sedimentation'. (W.H. Freeman and Co.: San Francisco).

Kusmer, K.D. (1990). Taphonomy of owl pellet deposition. *Journal of Paleontology* **64**, 629–637.

Lembit, R. (1988). Vegetation and weed management issues. In 'Jenolan Caves Reserve; Draft Plan of Management, volume 2' (Ed. Cameron McNamara) pp. 1–21. (Tourism Commission of New South Wales and Crown Lands Office: Sydney).

Levinson, M. (1982). Taphonomy of microvertebrates - from owl pellets to cave breccia. *Annals of the Transvaal Museum* **33**, 115–121.

Loyn, R.H., Traill, B.J. and Triggs, B.E., (1986). Prey of Sooty Owls in east Gippsland before and after fire. *Victorian Naturalist* **103**, 147–149.

Luckett, W.P. (1993). An ontogenetic assessment of dental homologies in therian mammals. In 'Mammal phylogeny' (Eds F.S. Szalay, M.J. Novacek and M.C. McKenna) pp. 182–204. (Springer-Verlag: New York).

Lundelius, E.L. (1963). Vertebrate remains from the Nullarbor Caves, Western Australia. *Journal of the Royal Society of Western Australia* **46**, 75–80.

Lundelius, E.L. (1966). Marsupial carnivore dens in Australian caves. *Studies in Speleology* **1**, 174–181.

Lunney, D. (1995). Bush Rat, *Rattus fuscipes*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 651–653. (Reed Books: Chatswood, NSW).

Lyne, A.G. and Mort, P.A. (1981). A comparison of skull morphology in the marsupial bandicoot genus *Isoodon*: its taxonomic implication and notes on a new species, *Isoodon arnhemensis*. *Australian Mammalogy* **4**, 107–133.

Mahoney, J.A. and Posamentier, H. (1975). The occurrence of the native rodent, *Pseudomys gracilicaudatus* (Gould, 1845) (Rodentia: Muridae), in New South Wales. *Australian Mammalogy* **1**, 333–346.

Marlow, B.J. (1958). A survey of the marsupials of New South Wales. *CSIRO Wildlife Research* **3**, 71–114.

McKay, G.M. (1988). Common Ringtail Possum, *Pseudocheirus peregrinus* and Greater Glider, *Petauroides volans*. In 'Australian Museum complete book of Australian mammals' (Ed. R. Strahan) pp. 126–127, 134. (Angus and Robertson: Sydney).

Merrilees, D. (1967). Fossil bandicoots (Marsupialia, Peramelidae) from Mammoth Cave, Western Australia, and their climatic implications. *Journal of the Royal Society of Western Australia* **50**, 121–128.

Merrilees, D. and Porter, J.K. (1979). 'Guide to the identification of teeth and some bones of native land mammals occurring in the extreme south west of Western Australia'. (Western Australian Museum: Perth).

Musser, G.G. (1981). The giant rat of Flores and its relatives east of Borneo and Bali. *Bulletin of the American Museum of Natural History* **169**, 67–176.

Peterson, J.A. (1968). Cirque morphology and Pleistocene ice formation conditions in southeastern Australia. *Australian Geographical Studies* **6**, 67–83.

Pettijohn, F.J. (1957). 'Sedimentary rocks'. (Harper and Row: New York).

Porter, J.K. (1979). Vertebrate remains from a stratified Holocene deposit in Skull Cave, Western Australia, and a review of their significance. *Journal of the Royal Society of Western Australia* **61**, 109–117.

Reineck, H.-E. and Singh, I.B. (1975). 'Depositional sedimentary environments'. (Springer-Verlag: Berlin).

Ride, W.D.L. (1960). The fossil mammalian fauna of the *Burramys parvus* breccia from the Wombeyan Caves, New South Wales. *Journal of the Royal Society of Western Australia* **43**, 74–80.

Ride, W.D.L. (1970). 'Native mammals of Australia'. (Oxford University Press: Melbourne).

Schodde, R. and Mason, I.J. (1980). 'Nocturnal birds of Australia'. (Lansdowne Editions: Melbourne).

Schram, F.R. and Turnbull, W.D. (1970). Structural composition and dental variations in the murids of the Broom Cave fauna, late Pleistocene, Wombeyan Caves area, New South Wales, Australia. *Records of the Australian Museum* **28**, 1–24.

Seebeck, J.H. (1976). The diet of the Powerful Owl, *Ninox strenua*, in western Victoria. *Emu* **76**, 167–170.

Soderquist, T. (1995). Brush-tailed Phascogale, *Phascogale tapoatafa*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 104–106. (Reed Books: Chatswood, NSW).

Smith, P. (1984). Prey items of the Sooty Owl and the Barn Owl at Bega, New South Wales. *Corella* **8**, 71–72.

Stanton, R. (1989). Sediment transport in the McKeowns Creek valley and the northern caves system at Jenolan, New South Wales. BSc (Hons.) thesis, Australian National University, Canberra.

Stodart, E. (1995). Long-nosed Bandicoot, *Perameles nasuta*. In 'The mammals of Australia' (Ed. R. Strahan) pp. 184–185. (Reed Books: Chatswood, NSW).

Strahan, R. (1995). 'The mammals of Australia'. (Reed Books: Chatswood, NSW).

Tate, G.H.H. (1951). Results of the Archbold Expeditions, number 65. The rodents of Australia and New Guinea. *Bulletin of the American Museum of Natural History* **97**, 183–430.

Taylor, J.M. and Horner, B.E. (1973). Results of the Archbold Expeditions, number 98. Systematics of native Australian *Rattus* (Rodentia, Muridae). *Bulletin of the American Museum of Natural History* **150**, 1–130.

Tilley, S. (1982). The diet of the Powerful Owl, *Ninox strenua*, in Victoria. *Australian Wildlife Research* **9**, 157–175.

Turnbull, W.D. and Schram, F.R. (1973). Broom Cave *Cercartetus*, with observations on Pygmy Possum dental morphology, variation, and taxonomy. *Records of the Australian Museum* **28**, 437–464.

Turner, V. (1988). Eastern Pygmy-possum, *Cercartetus nanus*. In 'Australian Museum complete book of Australian mammals' (Ed. R. Strahan) p. 160. (Angus and Robertson: Sydney).

Van Dyck, S.M. (1982). The relationships of *Antechinus stuartii* and *A. flavipes* (Dasyuridae, Marsupialia) with special reference to Queensland. In 'Carnivorous marsupials' (Ed. M. Archer) pp. 723–766. (Royal Zoological Society of NSW: Sydney).

Wakefield, N.A. (1960). Recent mammal bones in the Buchan district - 2. *Victorian Naturalist* **77**, 227–240.

Wakefield, N.A. (1967). Some taxonomic revision in the Australian marsupial genus *Bettongia* (Macropodidae), with description of a new species. *Victorian Naturalist* **84**, 8–22.

Wakefield, N.A. (1969). An investigation of late Pleistocene and Recent cave deposits insoutheastern Australia. MSc thesis, Monash University, Melbourne.

Wakefield, N.A. (1972). Palaeoecology of fossil mammal assemblages from some Australian caves. *Proceedings of the Royal Society of Victoria* **85**, 1–26.

Wakefield, N.A. and Warneke, R.M. (1967). Some revision in *Antechinus* (Marsupialia) -2. *Victorian Naturalist* **84**, 69–99.

Walton, D.W. (1988). 'Zoological catalogue of Australia, volume 5 Mammalia'. (Australian Government Publishing Service: Canberra).

Walton, D.W. and Richardson, B.J. (1989). 'Fauna of Australia. Mammalia, volume 1B'. (Australian Government Publishing Service: Canberra).

Ward, S.J. (1992). Life history of the Little Pygmy-possum, *Cercartetus lepidus* (Marsupialia: Burramyidae), in the Big Desert, Victoria. *Australian Journal of Zoology* **40**, 43–55.

Watts, C.H.S. and Aslin, H.J. (1981). 'The rodents of Australia'. (Angus and Robertson: London).

Wells, R.T., Moriarty, K. and Williams, D.L.G. (1984). The fossil vertebrate deposits of Victoria Fossil Cave Naracoorte: an introduction to the geology and fauna. *Australian Zoologist* **21**, 305–333.

Appendix A

A list of the published descriptions used in identifying the non-volant, native mammal species from the Nettle Cave deposit. The illustrated key to Australian Mammalia (Jones and Baynes 1989) was used to check all specimens.

Taxon	Reference
Antechinus	Davison (1986); Merrilees & Porter (1979); Van Dyck (1982); Wakefield & Warneke (1967)
Sminthopsis	Archer (1981); Merrilees & Porter (1979)
Phascogale	Merrilees & Porter (1979)
Dasyurus	Green (1983); Merrilees & Porter (1979)
Isoodon, Perameles	Freedman (1967); Freedman & Joffe (1967); Freedman & Rightmire (1971); Green (1983); Lyne & Mort (1981); Merrilees (1967); Merrilees & Porter (1979)
Pseudocheirus	Green (1983); Merrilees & Porter (1979)
Petaurus	Green (1983)
Petauroides	Archer (1984)
Cercartetus	Green (1983); Merrilees & Porter (1979); Turnbull & Schram (1973)
Burramys parvus	Dixon (1971)
Acrobates pygmaeus	Archer (1984)
Potorous	Green (1983); Merrilees & Porter (1979)
Bettongia	Green (1983); Merrilees & Porter (1979); Wakefield (1967)
Thylogale thetis	Green (1983)
Rattus	Green (1983); Merrilees & Porter (1979); Musser (1981); Tate (1951); Taylor & Horner (1973)
Pseudomys	Green (1983); Merrilees & Porter (1979); Schram & Turnbull (1970)
Mastacomys	Green (1983)

Appendix B

The minimum number of individuals (MNI) of small mammals and skinks identified from the Nettle Cave deposit. Birds and agamids are listed as present (yes) from the depth intervals of the deposit in which they were found. Depth intervals are in cm. The relative abundance (%) and aggregate (AGG), i.e. the total number of specimens of the mammal species in each depth interval is also given. L1, L2, etc. represents levels 1, 2 and so on. Depth intervals 41–39 cm and 13–5 cm were not analysed. 1. These do not represent new species in the relevant genus; the specimens were broken or lacking teeth, thus could not be assigned to a species with certainty. 2. If generic identification is correct, the species would be *M. schreibersii*. 3. If generic identification is correct, the species would be *C. gouldii*.

Depth interval Species	68–66 (L16) MNI (%) AGG	66–64 (15) MNI (%) AGG	64–59 (L14) MNI (%) AGG	59–54 (L13) MNI (%) AGG	54–50 (L12) MNI (%) AGG	50–46 (L11) MNI (%) AGG	46–44 (L10) MNI (%) AGG
DASYURIDAE	**1 (9.1) 1**	**2 (14.3) 2**	**3 (10.7) 3**	**3 (9.1) 4**	**3 (8.1) 6**	**7 (16.7) 9**	**8 (10.3) 12**
Antechinus stuartii sensu lato	0	0	0	0	0	0	1 (1.3) 1
A. swainsonii	0	1 (7.1) 1	1 (3.6) 1	2 (6.1) 3	2 (5.4) 4	2 (4.8) 4	1 (1.3) 1
A. flavipes	0	0	0	0	0	0	2 (2.6) 4
A. spp.[1]	0	0	0	1 (3) 1	0	3 (7.1) 3	2 (2.6) 3
Sminthopsis murina	0	0	1 (3.6) 1	0	1 (2.7) 2	0	1 (1.3) 2
S. sp.[1]	0	0	0	0	0	1 (2.4) 1	0
Phascogale tapoatafa	0	0	1 (3.6) 1	0	0	0	1 (1.3) 1
Dasyurus sp. cf. *D. viverrinus*	0	1 (7.1) 1	0	0	0	1 (2.4) 1	0
PERAMELIDAE	**1 (9.1) 1**	**0**	**2 (7.1) 2**	**1 (3) 1**	**1 (2.7) 1**	**1 (2.4) 1**	**1 (1.3) 1**
Isoodon obesulus	0	0	1 (3.6) 1	0	0	0	0
Perameles nasuta	1 (9.1) 1	0	1 (3.6) 1	1 (3) 1	1 (2.7) 1	1 (2.4) 1	1 (1.3) 1
PSEUDOCHEIRIDAE	**0**	**1 (7.1) 1**	**0**	**0**	**0**	**1 (2.4) 1**	**0**
Pseudocheirus peregrinus	0	1 (7.1) 1	0	0	0	1 (2.4) 1	0
Petauroides volans	0	0	0	0	0	0	0
PETAURIDAE	**1 (9.1) 1**	**0**	**0**	**0**	**1 (2.7) 1**	**0**	**0**
Petaurus breviceps	1 (9.1) 1	0	0	0	1 (2.7) 1	0	0
BURRAMYIDAE	**0**	**2 (14.3) 3**	**2 (7.1) 3**	**4 (12.1) 7**	**4 (10.8) 7**	**8 (19) 18**	**14 (17.9) 33**
Cercartetus nanus	0	0	0	0	0	0	0
C. lepidus	0	0	1 (3.6) 1	1 (3) 1	0	0	3 (3.8) 3
Burramys parvus	0	2 (14.3) 3	1 (3.6) 2	3 (9.1) 6	4 (10.8) 7	8 (19) 18	11 (14.1) 30
ACROBATIDAE	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Acrobates pygmaeus	0	0	0	0	0	0	0
POTOROIDAE	**0**	**0**	**0**	**0**	**0**	**0**	**1 (1.3) 1**
Potorous sp. cf. *P. tridactylus*	0	0	0	0	0	0	1 (1.3) 1
Bettongia sp.	0	0	0	0	0	0	0
MACROPODIDAE	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Thylogale thetis	0	0	0	0	0	0	0
MURIDAE	**8 (72.7) 14**	**9 (64.3) 19**	**21 (75) 46**	**25 (75.8) 60**	**28 (75.7) 62**	**24 (57.1) 53**	**52 (66.7) 138**
Conilurus albipes	0	0	0	0	0	0	0
Pseudomys oralis	1 (9.1) 1	1 (7.1) 2	4 (14.3) 7	3 (9.1) 8	3 (8.1) 7	3 (7.1) 4	6 (7.7) 16
P. gracilicaudatus	0	0	0	0	0	0	0
P. australis	0	1 (7.1) 1	1 (3.6) 1	2 (6.1) 3	2 (5.4) 2	0	2 (2.6) 4
P. novaehollandiae	0	0	0	0	0	0	0

44–43 (L9) MNI (%) AGG	43–41 (L8) MNI (%) AGG	39–37 (L6) MNI (%) AGG	37–35 (L5) MNI (%) AGG	35–25 (L4) MNI (%) AGG	25–13 (L3) MNI (%) AGG	5–0 (L1) MNI (%) AGG	SURFACE MNI (%) AGG
6 (16.7) 10	**14 (13.6) 33**	**51 (13.6) 115**	**92 (20.3) 198**	**175 (19.1) 324**	**90 (12.4) 197**	**235 (16.6) 564**	**13 (10.8) 32**
0	3 (2.9) 5	16 (4.3) 38	17 (3.8) 40	26 (2.8) 48	20 (2.8) 51	74 (5.2) 202	5 (4.2) 17
0	0	2 (0.5) 2	3 (0.7) 3	10 (1.1) 12	13 (1.8) 19	18 (1.3) 30	0
2 (5.6) 3	3 (2.9) 7	9 (2.4) 18	7 (1.5) 15	15 (1.6) 28	18 (2.5) 41	45 (3.2) 101	2 (1.7) 3
2 (5.6) 3	0	0	23 (5.1) 55	45 (4.9) 78	18 (2.5) 35	50 (3.5) 118	4 (3.3) 10
2 (5.6) 4	8 (7.8) 21	22 (5.9) 55	27 (6) 63	46 (5) 114	15 (2.1) 43	31 (2.2) 86	2 (1.7) 2
0	0	0	12 (2.6) 19	17 (1.9) 26	3 (0.4) 4	10 (0.7) 15	0
0	0	2 (0.5) 2	2 (0.4) 2	10 (1.1) 12	3 (0.4) 4	6 (0.4) 11	0
0	0	0	1 (0.2) 1	6 (0.7) 6	0	1 (0.1) 1	0
1 (2.8) 1	**3 (2.9) 3**	**11 (3) 16**	**22 (4.8) 27**	**31 (3.4) 45**	**21 (2.9) 38**	**34 (2.4) 43**	**1 (0.8) 1**
1 (2.8) 1	1 (1) 1	4 (1.1) 4	7 (1.5) 8	14 (1.5) 20	3 (0.4) 3	16 (1.1) 23	0
0	2 (1.9) 2	7 (1.9) 12	15 (3.3) 19	17 (1.9) 25	18 (2.5) 35	18 (1.3) 20	1 (0.8) 1
2 (5.6) 3	**5 (4.9) 5**	**8 (2.2) 12**	**13 (2.9) 33**	**15 (1.6) 31**	**26 (3.6) 65**	**62 (4.4) 136**	**21 (17.5) 56**
2 (5.6) 3	4 (3.9) 4	7 (1.9) 11	13 (2.9) 33	13 (1.4) 29	20 (2.8) 58	54 (3.8) 127	19 (15.8) 54
0	1 (1) 1	1 (0.3) 1	0	2 (0.2) 2	6 (0.8) 7	8 (0.6) 9	2 (1.7) 2
0	**4 (3.9) 8**	**12 (3.2) 24**	**19 (4.2) 44**	**26 (2.8) 60**	**33 (4.6) 70**	**107 (7.6) 306**	**43 (35.8) 136**
0	4 (3.9) 8	12 (3.2) 24	19 (4.2) 44	26 (2.8) 60	33 (4.6) 70	107 (7.6) 306	43 (35.8) 136
3 (8.3) 6	**1 (1) 1**	**3 (0.8) 3**	**2 (0.4) 2**	**4 (0.4) 4**	**0**	**10 (0.7) 15**	**0**
0	1 (1) 1	3 (0.8) 3	2 (0.4) 2	4 (0.4) 4	0	10 (0.7) 15	0
1 (2.8) 1	0	0	0	0	0	0	0
2 (5.6) 5	0	0	0	0	0	0	0
0	**0**	**5 (1.3) 7**	**4 (0.9) 6**	**6 (0.7) 6**	**0**	**11 (0.8) 16**	**0**
0	0	5 (1.3) 7	4 (0.9) 6	6 (0.7) 6	0	11 (0.8) 16	0
0	**0**	**4 (1.1) 4**	**5 (1.1) 5**	**5 (0.5) 5**	**6 (0.8) 6**	**8 (0.6) 9**	**0**
0	0	3 (0.8) 3	4 (0.9) 4	3 (0.3) 3	4 (0.6) 4	7 (0.5) 8	0
0	0	1 (0.3) 1	1 (0.2) 1	2 (0.2) 2	2 (0.3) 2	1 (0.1) 1	0
1 (2.8) 1	**0**	**0**	**1 (0.2) 1**	**0**	**0**	**0**	**0**
1 (2.8) 1	0	0	1 (0.2) 1	0	0	0	0
22 (61.1) 49	**74 (71.9) 192**	**277 (73.8) 755**	**294 (64.9) 839**	**649 (71) 1833**	**541 (74.8) 1485**	**932 (65.8) 2920**	**40 (33.3) 83**
0	1 (1) 1	2 (0.5) 2	6 (1.3) 7	23 (2.5) 57	2 (0.3) 2	1 (0.1) 1	2 (1.7) 2
3 (8.3) 8	17 (16.5) 44	80 (21.3) 253	98 (21.6) 320	236 (25.8) 740	256 (35.4) 860	465 (32.8) 1602	4 (3.3) 9
0	0	0	0	1 (0.1) 1	0	0	0
0	3 (2.9) 4	7 (1.9) 11	9 (2) 11	3 (0.3) 3	4 (0.6) 5	6 (0.4) 6	0
1 (2.8) 1	5 (4.9) 14	28 (7.5) 82	33 (7.3) 84	132 (14.4) 391	40 (5.5) 104	35 (2.5) 75	0

Species / Depth interval	68–66 (L16) MNI (%) AGG	66–64 (15) MNI (%) AGG	64–59 (L14) MNI (%) AGG	59–54 (L13) MNI (%) AGG	54–50 (L12) MNI (%) AGG	50–46 (L11) MNI (%) AGG	46–44 (L10) MNI (%) AGG
P. fumeus	0	1 (7.1) 1	1 (3.6) 1	2 (6.1) 4	2 (5.4) 2	2 (4.8) 5	5 (6.4) 16
P. spp.[1]	2 (18.2) 2	1 (7.1) 4	1 (3.6) 1	2 (6.1 6	2 (5.4) 2	5 (11.9) 11	7 (9) 22
Mastacomys fuscus	5 (45.5) 10	4 (28.6) 8	13 (46.4) 35	15 (45.5) 38	15 (40.5) 39	11 (26.2) 28	25 (32.1) 62
Rattus fuscipes	0	1 (7.1) 3	1 (3.6) 1	0	4 (10.8) 6	2 (4.8) 4	5 (6.4) 15
R. rattus	0	0	0	0	0	0	0
R. spp.[1]	0	0	0	1 (3) 1	0	1 (2.4) 1	2 (2.6) 3
Mus musculus	0	0	0	0	0	0	0
VESPERTILIONIDAE	**0**	**0**	**0**	**0**	**0**	**1 (2.4) 1**	**2 (2.6) 2**
Nyctophilus sp. cf. *N. gouldi*	0	0	0	0	0	0	1 (1.3) 1
N. sp. cf. *N. geoffroyi*	0	0	0	0	0	1 (2.4) 1	1 (1.3) 1
Miniopterus schreibersii	0	0	0	0	0	0	0
cf. *Miniopterus*[2]	0	0	0	0	0	0	0
Chalinolobus gouldii	0	0	0	0	0	0	0
C. morio	0	0	0	0	0	0	0
cf. *Chalinolobus*[3]	0	0	0	0	0	0	0
Falsistrellus tasmaniensis	0	0	0	0	0	0	0
LEPORIDAE	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Oryctolagus cuniculus	0	0	0	0	0	0	0
TOTAL MNI (%)	**11 (100)**	**14 (100)**	**28 (99.9)**	**33 (100)**	**37 (100)**	**42 (100)**	**78 (100.1)**
TOTAL AGGREGATE	17	26	54	72	77	83	187
AVES	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
AGAMIDAE	**0**	**0**	**0**	**0**	**0**	**0**	**0**
SCINCIDAE	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Egernia sp. cf. *E. whitii*	0	0	0	0	0	0	0
Eulamprus quoyii sp.-group	0	0	0	0	0	0	0
New taxon	0	0	0	0	0	0	0

44–43 (L9) MNI (%) AGG	43–41 (L8) MNI (%) AGG	39–37 (L6) MNI (%) AGG	37–35 (L5) MNI (%) AGG	35–25 (L4) MNI (%) AGG	25–13 (L3) MNI (%) AGG	5–0 (L1) MNI (%) AGG	SURFACE MNI (%) AGG
2 (5.6) 4	8 (7.8) 17	14 (3.7) 32	15 (3.3) 34	8 (0.9) 13	2 (0.3) 3	12 (0.8) 20	0
4 (11.1) 10	13 (12.6) 35	35 (9.3) 89	25 (5.5) 71	54 (5.9) 145	21 (2.9) 50	72 (5.1) 182	0
6 (16.7) 16	10 (9.7) 24	25 (6.7) 63	22 (4.9) 57	31 (3.4) 69	47 (6.5) 139	77 (5.4) 213	3 (2.5) 4
6 (16.7) 10	16 (15.5) 51	63 (16.8) 184	68 (15) 220	118 (12.9) 339	151 (20.9) 292	201 (14.2) 701	13 (10.8) 31
0	0	0	0	0	0	42 (3) 83	16 (13.3) 32
0	1 (1) 1	23 (6.1) 39	18 (4) 35	43 (4.7) 75	18 (2.5) 30	19 (1.3) 33	0
0	0	0	0	0	0	2 (0.1) 4	2 (1.7) 5
1 (2.8) 1	**2 (1.9) 2**	**4 (1.1) 4**	**1 (0.2) 1**	**3 (0.3) 4**	**6 (0.8) 6**	**16 (1.1) 25**	**1 (0.8) 1**
0	0	0	0	0	1 (0.1) 1	3 (0.2) 3	0
1 (2.8) 1	1 (1) 1	2 (0.5) 2	0	2 (0.2) 3	0	2 (0.1) 3	0
0	0	0	0	0	5 (0.7) 5	8 (0.6) 12	1 (0.8) 1
0	0	0	0	1 (0.1) 1	0	0	0
0	0	1 (0.3) 1	0	0	0	1 (0.1) 3	0
0	0	0	0	0	0	1 (0.1) 1	0
0	1 (1) 1	0	1 (0.2) 1	0	0	0	0
0	0	1 (0.3) 1	0	0	0	1 (0.1) 3	0
0	**0**	**0**	**0**	**0**	**0**	**1 (0.1) 1**	**1 (0.8) 2**
0	0	0	0	0	0	1 (0.1) 1	1 (0.8) 2
36 (100.1)	**103 (100.1)**	**375 (100.1)**	**453 (99.9)**	**914 (99.8)**	**723 (99.9)**	**1416 (100.1)**	**120 (99.8)**
71	244	940	1156	2312	1867	4035	311
yes	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
0	**0**	**yes**	**yes**	**yes**	**yes**	**yes**	**0**
0	**0**	**0**	**0**	**0**	**2**	**1**	**0**
0	0	0	0	0	1	0	0
0	0	0	0	0	1	0	0
0	0	0	0	0	0	1	0